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TITLE: Vehicle steering control system

Abstract Text (1):
In a vehicle steering control system, an actuating torque is applied to steerable wheels according to a steering torque applied to a steering wheel in a conventional manner, and an additional actuating torque is applied to the steering wheel by an electric motor according to lateral dynamic conditions of the vehicle so as to control the lateral stability of the vehicle even in the presence of external interferences such as crosswind. Such external interferences are detected as a lateral dynamic condition of the vehicle such as the yaw rate of the vehicle, and the steering control system produces a steering reaction which counteracts such a lateral dynamic condition by applying the additional actuating torque to the steerable wheels so that the vehicle may maintain a straight course in spite of such external interferences without requiring any intentional efforts by the vehicle operator. By appropriate selection of the gain of the system for generating the additional actuating torque, this advantage can be gained without causing any excessive reaction when the vehicle is undergoing a normal turning maneuver.

Brief Summary Text (2):
The present invention relates to a vehicle steering control system, and in particular to a steering control system capable of producing a steering torque that tends to control the irregular behavior of the vehicle when the vehicle is subjected to crosswind or other external interferences.

Brief Summary Text (4):
Conventionally, the power steering system is known, and according to the power steering system disclosed in Japanese patent publication No. 50-33584, the steering effort or torque applied to a steering wheel is assisted by an output torque from an electric motor. The gain of the system for the signal obtained by detecting the steering torque applied to the steering wheel by the vehicle operator is varied according to the vehicle speed and the road condition, and the output torque of the assisting electric motor is accordingly changed so that the optimum actuating torque which actually steers the front wheels may be obtained at all times.

Brief Summary Text (5):
When the vehicle is abruptly subjected to a strong crosswind while travelling a straight course, the vehicle may deviate from the intended straight path of travel. In such a case, it is necessary to apply a counteracting force to the steerable wheels so as to oppose such interferences. However, according to such a conventional power steering system, when the vehicle has started deviating from the intended path as a result of crosswind, because the electric motor can produce an actuating torque only when the vehicle operator applies a steering torque to the steering wheel, the electric motor cannot produce any actuating torque unless the vehicle operator intentionally takes a corrective action.

Brief Summary Text (6):
To control the deviation of the vehicle from the intended straight path, the vehicle operator must apply a corrective steering torque to the steering wheel.

However, according to the conventional power steering system, the required steering torque increases as the lateral acceleration and the yaw rate of the vehicle increase, and, accordingly, the steering torque required for counteracting the deviation of the vehicle due to external interferences increases as the lateral acceleration and the yaw rate of the vehicle increase.

Brief Summary Text (7):
Furthermore, the conventional power steering system requires a very small steering torque for its operation, but the vehicle operator receives very little feedback from the steering wheel with regard to the behavior of the vehicle. Therefore, the vehicle operator must depend on his vision and bodily sense of acceleration in assessing the condition of the vehicle when it is subjected to external interferences. As a result, the counter-action by the vehicle operator tends to be delayed, and, therefore, tends to be excessive.

Brief Summary Text (9):
However, according to such a control system based on the use of an electric motor, because the system cannot determine whether the detected yaw rate is due to an intentional steering maneuver or due to external interferences, the electric motor always produces a steering torque which tends to control the yaw rate or which tends to restore the vehicle back to the straight ahead path of travel irrespective of the cause of the yawing movement. As a result, the steering reaction which the electric motor produces may become excessive when the vehicle is making a normal turn. If the control parameters are modified so that the steering reaction may be appropriate at the time of normal steering maneuver, the vehicle may not be sufficiently protected from external interferences.

Brief Summary Text (12):
A second object of the present invention is to provide an improved vehicle steering control system which is capable of controlling the deviation of the vehicle from an intended path of travel even when the vehicle is subjected to disturbances such as crosswind, and maintaining the steering torque required for the steering maneuver at an appropriate level.

Brief Summary Text (13):
A third object of the present invention is to provide a vehicle steering control system which can maintain the vehicle on a straight path even when the vehicle is subjected to disturbances such as crosswind, without requiring any efforts from the operator of the vehicle.

Brief Summary Text (14):
According to the present invention, these and other objects can be accomplished by providing a vehicle steering control system, comprising steering torque input means; powered steering control means for applying a first actuating torque to steerable wheels of a vehicle according to a steering torque applied to the steering torque input means; means for detecting a lateral dynamic condition of the vehicle; and active reaction generating means for applying a second actuating torque to the steerable wheels so as to control a turning movement of the vehicle according to a signal supplied from the detecting means; whereby an overall actuating torque applied to the steerable wheels comprises a sum of the first and second actuating torques provided by the powered steering control means and the active reaction generating means. The lateral dynamic condition may include such parameters as the yaw rate and the lateral acceleration of the vehicle and their time derivatives.

Brief Summary Text (15):
Thus, the irregular movement of the vehicle is detected in terms of the yaw rate or the lateral acceleration of the vehicle caused by external interferences, and the actuating torque for the steerable wheels counteracting the irregular movement can be produced by the active reaction generating means. In particular, when the second

actuating torque provided by the active reaction generating means comprises a component which depends on a change rate of the lateral dynamic condition of the vehicle detected by the detecting means, the response of the steering control system is speeded up, and a favorable transient property can be obtained.

Brief Summary Text (16):
Preferably, a contribution of the second actuating torque to the overall actuating torque increases as a vehicle speed increases because higher vehicle speed means greater influences from the external interferences, and the compensatory action must be increased as the vehicle speed is increased.

Brief Summary Text (17):
According to a preferred embodiment of the present invention, the second actuating torque provided by the active reaction generating means is greater near a neutral point of the steering torque input means than in a larger steering angle range of the steering torque input means. Thus, the second actuating torque produced by an electric motor or the like is diminished by the increase in the steering angle, and the vehicle operator can therefore comfortably carry out the normal turning maneuver typically involving relatively large steering angles without being hampered by any undesired excessive steering reaction.

Brief Summary Text (18):
When the vehicle is making a normal turn, it will also give rise to a yaw rate and a lateral acceleration, and a moderate steering reaction is applied by the electric motor to the steering shaft so as to restore the vehicle to a straight ahead course or the steering wheel to its neutral position. Such a steering reaction similar to the self-aligning torque, when produced at a moderate level, facilitates the vehicle operator's effort in turning the steering wheel back to its neutral position upon completion of the turning maneuver.

Brief Summary Text (19):
According to another preferred embodiment of the present invention, the second actuating torque provided by the active reaction generating means comprises a component which depends on a deviation of an actually detected lateral dynamic condition from a reference lateral dynamic condition which is predicted from a steering input to the steering torque input means. Thus, when the vehicle is travelling under normal condition, either making a turn or travelling straight ahead, the deviation is small, and the steering control system operates much in the same way as the conventional power steering system. However, when the deviation becomes substantial, for instance, due to the influences from external interferences such as crosswind, the resulting steering reaction counteracts such a deviation, and maintains the vehicle on the intended path of travel.

Detailed Description Text (4):
The steering shaft 4 is provided with a steering angle sensor 15 for producing a signal corresponding to the rotational angle of the steering wheel 3 and a torque sensor 16 for producing a signal corresponding to a steering torque applied to the steering shaft 4.

Detailed Description Text (6):
In this embodiment, the steering wheel 3 and the steerable wheels or the front wheels 9 are mechanically connected to each other, and a control signal obtained by processing the outputs from the various sensors 15 through 19 is supplied to the electric motor 10 via a control unit 20 and a drive circuit 21 so that the output torque of the electric motor 10 may be controlled as required.

Detailed Description Text (7):
FIG. 2 shows a schematic block diagram of a control system to which the present invention is applied. The control unit 20 receives the outputs from the steering angle sensor 15, the torque sensor 16, the lateral acceleration sensor 17, the yaw

rate sensor 18, and the vehicle speed sensor 19. These output signals are fed to an electric power steering control unit 22 and an active steering reaction computing unit 23, and the outputs from these units are supplied to an output current determining unit 24 so that the target electric current level for the electric motor 10 may be determined.

Detailed Description Text (8):
The electric power steering control unit 22 carries out the control for the normal power assist for the steering force or the actuating torque for the steerable front wheels 9. This control unit 22 may be capable of determining the target actuating torque according to the lateral acceleration and the yaw rate.

Detailed Description Text (9):
The active steering reaction computing unit 23 computes the target actuating torque according to an algorithm which is described hereinafter. The output current determining unit 24 determines the target driving current signal which is proportional or otherwise corresponds to the deviation of the actual steering torque obtained from the torque sensor 16 from the target steering torque value. The target driving current signal is however opposite in sign to the deviation.

Detailed Description Text (17):
The target steering reaction TA thus determined is added to the target assisting actuating torque, and the sum is converted into a target electric current level by the output current determining unit 24 to be supplied to the drive circuit 21 (FIG. 2).

Detailed Description Text (18):
Thus, when the vehicle 25 deviates from the intended straight path 26 due to crosswind as illustrated in FIG. 10, the lateral acceleration G and the yaw rate .gamma. of the vehicle are detected, and the electric motor 10 is activated in such a manner that the lateral acceleration G and the yaw rate .gamma. of the vehicle 25 may be cancelled even in absence of any intentional efforts to turn the steering wheel 3 by the vehicle operator, or that the deviation of the vehicle 25 from the straight path 26 may be eliminated and the vehicle 25 may be brought back on the straight path 26.

Detailed Description Text (19):
On the other hand, when the vehicle is making a turning maneuver as a result of an intentional effort by the vehicle operator without any external interferences, the turning movement of the vehicle also produces a yaw rate and a lateral acceleration. However, because the steering angle is substantially great, the reaction torque produced by the electric motor is diminished by the increase in the steering angle as described previously with reference to FIG. 9, and the vehicle operator can comfortably carry out the turning maneuver without being hampered by any undesired excessive steering reaction.

Detailed Description Text (20):
Thus, when the vehicle 25 is subjected to a yaw rate .gamma. and a lateral acceleration G, and the vehicle operator is not applying any steering effort to the steering wheel, the front wheels 9 are automatically steered so as to restore the vehicle 25 to the straight path without involving any irregular behavior of the vehicle. Even when the vehicle operator is holding on to the steering wheel 3, the same result can be achieved if he simply follows the movement of the steering wheel 3. During the normal cruising condition of the vehicle, the vehicle operator can sense the behavior of the vehicle from the steering torque acting upon the steering wheel or the steering reaction produced by the electric motor 10, and can therefore comfortably operate the vehicle. Furthermore, the vehicle operator can handle the vehicle at will by turning the steering wheel against the steering reaction if he wishes to intentionally do so.

Detailed Description Text (23):
When the vehicle is making a normal turn, it wile also give rise to a yaw rate and a lateral acceleration, and a moderate steering reaction is applied by the electric motor to the steering shaft so as to restore the vehicle to a straight ahead course or the steering wheel to its neutral position. Such a steering reaction similar to the self-aligning torque facilitates the vehicle operator's effort in turning the steering wheel back to its neutral position upon completion of the turning maneuver.

Detailed Description Text (24):
Depending on the property and the condition of the vehicle, it may demonstrate a tendency of abruptly developing an over-steer condition during a turning maneuver. However, when the vehicle is equipped with the steering system of the present invention, an abrupt increase in the yaw rate due to the abrupt onset of the over-steer condition produces a steering reaction which assists the vehicle operator's effort to counteract the over-steer condition by a compensatory steering operation. Conversely, when the vehicle develops a tendency to slip sideways, as it causes no substantial yaw movement or lateral acceleration, the vehicle operator can increase the steering angle without being hampered by the reaction force from the steering wheel.

Detailed Description Text (26):
Thus, according to the present invention, the actuating torque that tends to control the lateral movement of the vehicle is applied to the steerable wheels and the irregular lateral movement of the vehicle due to external interferences such as crosswind can be effectively controlled without requiring any efforts on the part of the vehicle operator. The vehicle equipped with this steering control system therefore demonstrates a highly stable behavior in following a straight course. Furthermore, when this reaction is reduced as the steering angle is increased, the steering reaction during the normal turning maneuver is not undesirably increased. By proper selection of the parameters, it is possible to achieve both a favorable stability of the vehicle in its cruising condition and an appropriate level of steering reaction during normal turning maneuvers.

Detailed Description Text (27):
Furthermore, because the vehicle operator can restrain or turn the steering wheel at will against the steering reaction produced by the assisting electric motor, the handling of the vehicle is not substantially affected by the provision of the steering control system, and can sense the condition of the vehicle from the steering reaction transmitted to the steering wheel.

Detailed Description Text (32):
Step 3 is carried out as described previously with reference to FIG. 6. This process corresponds to the action of the limiter L in FIG. 14. The target steering reaction TA' thus determined is added to the target assisting actuating torque, and the sum is converted into a target electric current level by the output current determining unit 24 to be supplied to the drive circuit 21.

Detailed Description Text (33):
Thus, when the vehicle 25 deviates from the intended straight path 26 due to crosswind as illustrated in FIG. 10, the deviation .gamma.-.gamma..sub.0 between the current yaw rate .gamma. and the reference yaw rate response model .gamma..sub.0 is detected, and the electric motor is activated in such a manner that the deviation .gamma.-.gamma..sub.0 may be eliminated even in absence of any intentional efforts to turn the steering wheel 3 by the vehicle operator, or that the deviation of the vehicle 25 from the straight path 26 may be eliminated and the vehicle 25 may be brought back on the straight path 26.

Detailed Description Text (34):
Thus, even when the vehicle 25 is subjected to a yaw rate .gamma. due to crosswind

or other interferences, and the vehicle operator is not applying any steering effort to the steering wheel, the front wheels 9 are automatically steered so as to restore the vehicle 25 to the straight path without involving any irregular behavior of the vehicle. Even when the vehicle operator is holding on to the steering wheel 3, the same result can be achieved if he simply follows the movement of the steering wheel 3.

Detailed Description Text (35):
When the vehicle is making a turn without involving any substantial external interferences, some yaw rate is produced, but the deviation .gamma.-.gamma..sub.0 between the current yaw rate .gamma. and the reference yaw rate response model .gamma..sub.0 is so small and the contribution of the deviation to the steering reaction is therefore so small that the vehicle operator can complete the turning maneuver without encountering any excessive steering reaction. Thus, advantages substantially identical to those of the first embodiment can be achieved.

CLAIMS:

1. A vehicle steering control system, comprising:

steering torque input means;

powered steering control means for applying a first actuating torque to steerable wheels of a vehicle according to a steering torque applied to said steering torque input means;

means for detecting a lateral dynamic condition of said vehicle; and

active reaction generating means for applying a second actuating torque to said steerable wheels so as to control a turning movement of said vehicle according to a signal supplied from said detecting means, said active reaction generating means applying said second actuating torque during all traveling conditions of the vehicle such that an appropriate steering reaction is applied to a steering wheel of the vehicle during said all traveling conditions of the vehicle;

whereby an overall actuating torque applied to said steerable wheels comprises a sum of said first and second actuating torques provided by said powered steering control means and said active reaction generating means.

2. A vehicle steering control system according to claim 1, wherein said second actuating torque provided by said active reaction generating means comprises a component which depends on a change rate of said lateral dynamic condition of said vehicle detected by said detecting means.

3. A vehicle steering control system according to claim 1, wherein a contribution of said second actuating torque to said overall actuating torque increases as a vehicle speed increases.

4. A vehicle steering control system according to claim 1, wherein said overall actuating torque applied to said steerable wheels consists of the sum of said first and second actuating torques.

5. A vehicle steering control system according to claim 1, wherein said second actuating torque provided by said active reaction generating means comprises a component which depends on a deviation of an actually detected lateral dynamic condition from a reference lateral dynamic condition which is predicted from a steering input to said steering torque input means.

10. A vehicle steering control system according to claim 1, wherein said powered

steering control means and said active reaction generating means jointly comprise a steering force generating unit connected to a steering rod, the steering rod is operatively connected to the steerable wheels, and said steering force generating unit concurrently applies said first and second actuating torque to said steerable wheels as said overall actuated torque.

12. A vehicle steering control system according to claim 10, wherein said steering torque input means applies a manual steering torque to said steerable wheels in addition to the overall actuating torque applied to the steerable wheels.

13. A vehicle steering control system, comprising:

steering torque input means;

lowered steering control means for applying a first actuating torque to steerable wheels of a vehicle according to a steering torque applied to said steering torque input means;

means for detecting a lateral dynamic condition of said vehicle;

active reaction generating means for applying a second actuating torque to said steerable wheels so as to control the turning movement of said vehicle according to a signal supplied from said detecting means, said active reaction generating means applying said second actuating torque during all traveling conditions of the vehicle;

whereby an overall actuating torque applied to said steerable wheels comprises a sum of said first and second actuating torques provided by said powered steering control means and said active reaction generating means; and

said second actuating torque provided by said active reaction generating means being reduced as a steering angle of the vehicle increases.

14. A vehicle steering control system, comprising:

steering torque input means;

powered steering control means for applying a first actuating torque to steerable wheels of the vehicle according to a steering torque applied to said steering torque input means;

means for detecting a lateral dynamic condition of said vehicle;

active reaction generating means for applying a second actuating torque to said steerable wheels so as to control a turning movement of said vehicle according to a signal supplied from said detecting means, said active reaction generating means applying said second actuating torque during all traveling conditions of said vehicle;

whereby an overall actuating torque applied to said steerable wheels comprises a sum of said first and second actuating torques provided by said powered steering control means and said active reaction generating means; and

said second actuating torque provided by said active reaction generating means being greater near a neutral point of said steering torque input means than in a larger steering angle range of said steering torque input means.